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DYNAMIC ANALYSIS TO ESTABLISH NORMAL SHOCK AND VIBRATION OF RADIOACTIVE MATERIAL SHIPPING PACKAGES

QUARTERLY PROGRESS REPORT
JANUARY 1, 1981 - MARCH 31, 1981

Hanford Engineering Development Laboratory

S.R. Fields

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DYNAMIC ANALYSIS TO ESTABLISH NORMAL SHOCK AND VIBRATION OF RADIOACTIVE MATERIAL SHIPPING PACKAGES

Quarterly Progress Report

January 1, 1981 - March 31, 1981

S. R. Fields

ABSTRACT

The CARDS (Cask Rail Car Dynamic Simulator) model was expanded to simulate the cask-rail car system used in Tests 10 and 11 of the series of rail car coupling tests conducted at the Savannah River Laboratories (SRL) in July and August of 1978. An assessment of how well CARDS simulates the behavior of this cask-rail car system was made by comparing calculated and experimental values of four response variables. The processing and interpretation of the data from Tests 10, 11, 13, 16, 17 and 18 of the SRL series has been completed.

ACKNOWLEDGMENT

I would like to acknowledge the excellent work of M. S. Nutter and C. Bromley (Boeing Computer Services of Richland), and H. A. Carlson (Hanford Engineering Development Laboratory) who were instrumental in the processing and interpretation of the data from the Savannah River Tests.

S. R. Fields

CONTENTS

FIGURES

TABLES

DYNAMIC ANALYSIS TO ESTABLISH NORMAL SHOCK AND VIBRATION OF RADIOACTIVE MATERIAL SHIPPING PACKAGES

Quarterly Progress Report
January 1, 1981 - March 1, 1981

SUMMARY OF PROGRESS

1. DEVELOP DYNAMIC MODEL

The CARDS (Cask Rail Car Dynamic Simulator) model was expanded to simulate the cask-rail car system used in Tests 10 and 11 of the series of rail car coupling tests conducted at the Savannah River Laboratories (SRL) in July and August of 1978. CARDS was modified to allow the simulation of Tests 10 and 11 without disturbing the calculational sequence already in place for the simulation of Test 3.

2. DATA COLLECTION AND REDUCTION

The processing and interpretation of the data from Tests 10, 11, 13, 16, 17 and 18 conducted at SRL has been completed. These data, reduced and filtered, are now available for comparison with calculated results to be obtained from simulations of these tests using the CARDS model.

3. VALIDATE MODEL

An assessment of how well CARDS simulates the behavior of the cask-rail car system, for the conditions of Tests 10 and 11, was made by comparing the calculated and experimental values of the longitudinal force of interaction between the cask and rail car, the horizontal acceleration of the rail car, the horizontal acceleration of the cask, and the vertical acceleration of the of the cask at the far end. The coupler force measured during these tests was used as the force of excitation causing the simulated system to vibrate.

For Test 10, all of the above response variables compare well with their experimental counterparts, except for the vertical acceleration of the cask at the far end. Evidence is presented which indicates that the experimentally measured vertical acceleration of the cask at the far end is in error.

For Test 11, all of the above response variables compare well with the corresponding experimental data, except for the horizontal acceleration of the rail car. Apparently the accelerometers recording the horizontal acceleration of the rail car were either faulty or overranged, because the data obtained were not suitable for use.

INTRODUCTION

The objective of this study is to determine the extent to which the shocks and vibrations experienced by radioactive material shipping packages during normal transport conditions are influenced by or are sensitive to various structural parameters of the transport system (i.e., package, package supports, and vehicle). The purpose of this effort is to identify those parameters which significantly affect the normal shock and vibration environments so as to provide the basis for determining the forces transmitted to radioactive material packages. Determination of these forces will provide the input data necessary for a broad range of package-tiedown structural assessments.

Progress on this study from January 1, 1981 to March 31, 1981 will now be discussed.

PROGRESS TO DATE

This study is divided into six tasks as discussed in previous progress reports. Progress on each of these tasks will now be discussed.

1. DEVELOP DYNAMIC MODEL

The CARDS (Cask Rail Car Dynamic Simulator) model was expanded to simulate the cask-rail car system used in Tests 10 and 11 of the series of rail car coupling tests conducted at the Savannah River Laboratories (SRL) in July and August of 1978. Prior to this, CARDS was set up to simulate the cask-rail car system used in Test 3 of the series.

The primary differences between the cask-rail car system used in Test 3 and that used in Tests 10 and 11 are due to the types of casks used and the methods used for their attachment to the rail car (tiedown system). The same rail car used in Test 3 was used in Tests 10 and 11. The box-shaped 70-ton cask used in Tests 10 and 11, unlike the cylindrical 40-ton Hallam cask used in Test 3 and the rest of the tests, did not require a cradle structure which became part of the tiedown structure. The 70-ton cask was bolted directly to the rail structure. See Section 3, VALIDATE MODEL, for a discussion of these two different tiedown systems.

CARDS was modified to allow the simulation of Tests 10 and 11 without disturbing the calculational sequence already in place for the simulation of Test 3. This was accomplished by setting up branching calculation flow paths within the model. This procedure will be used for each of the remaining tests to be simulated, i.e., Tests 13, 17 and 18.

2. DATA COLLECTION AND REDUCTION

The processing and interpretation of the data from Tests 10, 11, 13, 16, 17 and 18, conducted at SRL in July and August of 1978, has been completed. These data, reduced and filtered, are now available for comparison with calculated results to be obtained from simulations of these tests using the CARDS model.

3. VALIDATE MODEL

An assessment of how well the CARDS model simulates the behavior of the cask-rail car system for the conditions of Tests 10 and 11, of the series of tests conducted at SRL in July and August of 1978, was made by comparing the calculated and experimental values of the longitudinal force of interaction between the cask and rail car, the horizontal acceleration of the rail car, the horizontal acceleration of the cask, and the vertical acceleration of the cask at the far end. The coupler force measured during these tests was used as the force of excitation causing the system simulated by CARDS to vibrate. This coupler force is shown in Figures 1 and 8 for Tests 10 and 11, respectively.

The cask-rail car system used in Tests 10 and 11 consisted of a 70-ton cask mounted on a flat bulkhead rail car with standard couplers (for test configurations and conditions, see Table 1 and Figure 2). The cask used in these tests was a rectangular box-shaped 70-ton cask used for onsite shipments at SRL. The rail car was the same one used in Test 3. When the base of the cask was placed in contact with the bumper beams between the cask and the load cells, its vertical centerline (fore and aft) fell almost 8.0 feet forward [toward the struck end (SE)] of the rail car centerline. This offset placed the far end (FE) of the cask almost directly over the center of gravity of the rail car.

For Test 10, the calculated longitudinal force of interaction between the cask and rail car, the horizontal acceleration of the rail car, the horizontal acceleration of the cask, and the vertical acceleration of the cask at the far end are compared with corresponding experimental data in Figures 3, 4, 5 and 6, respectively. All of these response variables compare well with their experimental counterparts, except for the vertical acceleration of the cask at the far end. The peak values of the calculated vertical acceleration of the cask in Figure 6 are substantially lower than the peaks on the plot of the experimental data. There is evidence which indicates that the experimental data may be in error. First, these vertical accelerations of the cask are compared, in Figure 6, to the calculated vertical acceleration of a point on the rail car over the trucks at the far end. The agreement between this calculated vertical rail car acceleration and the experimental data for the vertical acceleration of the cask is better than that between the calculated and experimental values of the vertical accelerations of the cask. This would mean that the far end of the cask was pitching as much as the far end of the rail car. This does not seem reasonable in view of the statement made earlier that the far end of the cask was located almost directly above the center of gravity (c.g.) of the rail car. There is rotation about the c.g. of the rail car, but the vertical motion of the rail car at this point is substantially less than that of the rail car over the trucks at the struck and far ends. The second piece of evidence which indicates that the experimental data from Test 10 may be in error is found by moving forward in the text to Figure 12 where the vertical acceleration of the cask at the far end, calculated for Test 11 conditions, is compared to the same vertical acceleration measured during Test 11. Figure 12 shows that very good agreement exists between the calculated and experimental values of this acceleration, and that they both differ substantially from a superimposed plot of the vertical acceleration of a point on the rail car over the trucks at the far end. The only changes made to CARDS in proceeding from the simulation of Test 10 to the simulation of Test 11 were (1) the impact velocity was increased from 8.0 miles per hour to 11.2 miles per hour, and (2) the coupler force recorded during Test 11 (Figure 8) replaced that from Test 10 (Figure 1) as the force of excitation applied at the coupler. None of the structural parameters of the cask-rail car system were changed.

Two key assumptions were made when the parameters were prepared for insertion into CARDS for the simulation of Tests 10 and 11. First of all, it was assumed that the vertical components of the tiedowns were tight. This is in contrast to the simulation of the cask-rail car system of Test 3 where some looseness, and the installation of rubber bushings in the collar at the far end of the 40-ton Hallam cask, required the use of a non-linear stiffness coefficient to represent the vertical component of the tiedown structure (see

Reference 1). The 70-ton cask used in Tests 10 and 11, unlike the 40-ton Hallam cask used in the rest of the tests, did not require a cradle structure which became part of the tiedown structure. The 70-ton cask was bolted directly to the rail car structure. The assumption of tight vertical tie-downs for Tests 10 and 11 appears to be justified by the good agreement between the calculated and experimental values of the vertical acceleration of the far end of the cask, for Test 11, as shown in Figure 12.

The horizontal component of the tiedowns, in Tests 10 and 11, consisted of a rigid welded stop to restrain the cask from moving longitudinally. Initially, it was assumed that the stiffness coefficient of this horizontal component was a constant. Several values, ranging up to 5×10^6 lbs/inch, were tried, however, none of these trial simulations produced results that matched the experimental data. These simulations suggested that a non-linear stiffness coefficient was required for the horizontal component of the tiedowns. Consequently, this was the second assumption made for the simulation of Tests 10 and 11. It was assumed that a constant stiffness coefficient of 1.0×10^5 lbs(force)/inch was valid up to a relative displacement between the cask and rail car of about 0.2 inch and that, after this initial movement, the tiedowns yielded and could be represented by the non-linear stiffness coefficient shown in Figure 7. This stiffness coefficient was established for Test 10 and used, without change, for the simulation of Test 11.

For Test 11, the calculated longitudinal force of interaction between the cask and rail car, the horizontal acceleration of the cask, and the vertical acceleration of the cask at the far end are compared with experimental data in Figures 9, 11 and 12, respectively. The calculated horizontal acceleration of the rail car is presented in Figure 10. In the comparisons for Test 10, this acceleration was compared to data from instrument 12. However, in Test 11 the data from instrument 12, and from all other instruments measuring the horizontal acceleration of the car, were not suitable for use, so no experimental data are shown in Figure 10. Except for the horizontal acceleration of the car, all of the response variables listed above compare well with the corresponding experimental data.

There is some uncertainty with regard to the measured coupler force shown in Figure 8. The experimental traces show that, from about 0.2 second to about 0.5 second, this coupler force leveled off at a value of about 200,000 lbs(force) rather than 0. In contrast, the coupler force measured for Test 10 dropped to zero force after about 0.25 second. It is not known whether this failure to drop to zero, as would be expected, is due to a faulty instrument and, if so, at what point along the trace the instrument went awry. A comparison of the coupler force plots in Figures 1 and 8 suggests that the instrument for Test 11 might have experienced some difficulty at about 0.2 second.

The experimental acceleration data used in the above comparisons contained high frequency noise that had to be filtered out before the comparisons could be made. As indicated on Figures 4 through 6, and Figures 10 through 12, the horizontal acceleration data were filtered at 100 Hz and the vertical acceleration data at 50 Hz. Filtering of the high frequency noise components from these data was accomplished using the FFT (Fast Fourier Transform) program.[2,3]

4. COLLECT PARAMETER DATA

There has been no activity in this task during this reporting period.

5. PARAMETRIC AND SENSITIVITY ANALYSIS

There has been no activity in this task during this reporting period.

6. INTERIM REPORT

There has been no activity in this task during this reporting period.

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2. Fields, S. R. and Mech, S. J., Dynamic Analysis to Establish Normal Shock and Vibration of Radioactive Material Shipping Packages, NUREG/CR-0766 (HEDL-TME 79-3), Quarterly Progress Report (October 1, 1978 - December 31, 1978) July 1979.

3. Fields, S. R. and Mech, S. J., Dynamic Analysis to Establish Normal Shock and Vibration of Radioactive Material Shipping Packages, NUREG/CR-1066 (HEDL-TME 79-43), Quarterly Progress Report (April 1, 1979 - June 30, 1979), October 1979.

The above reports are available for purchase from the NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission, Washington, DC 20555, and/or the National Technical Information Service, Springfield, VA 22161.

APPENDIX A - Figures

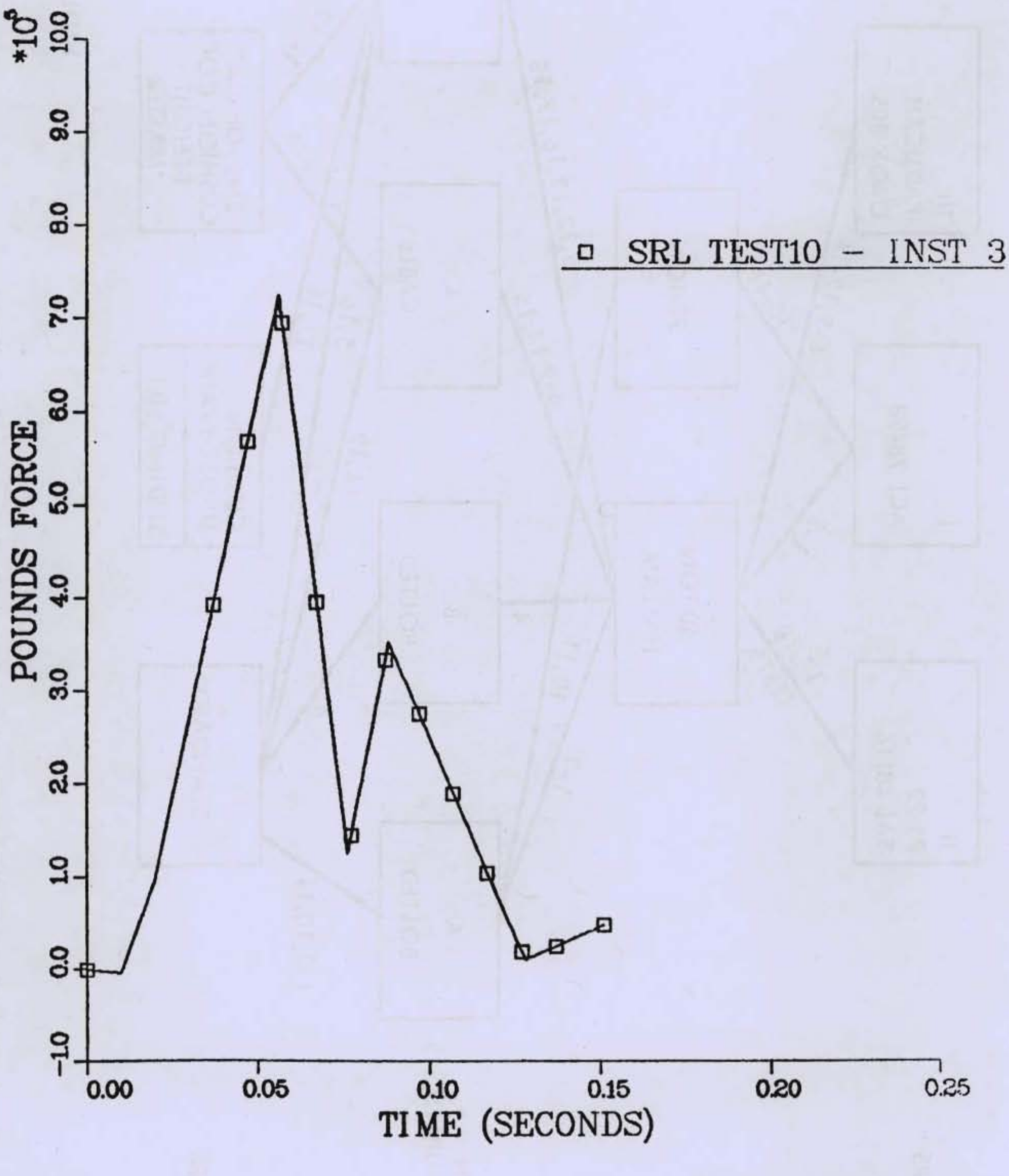

FIGURE 1. Coupler Force vs Time During Impact of Cask-Rail Car with Four Hopper Cars Loaded with Ballast (Test 10 - Instrument 3).

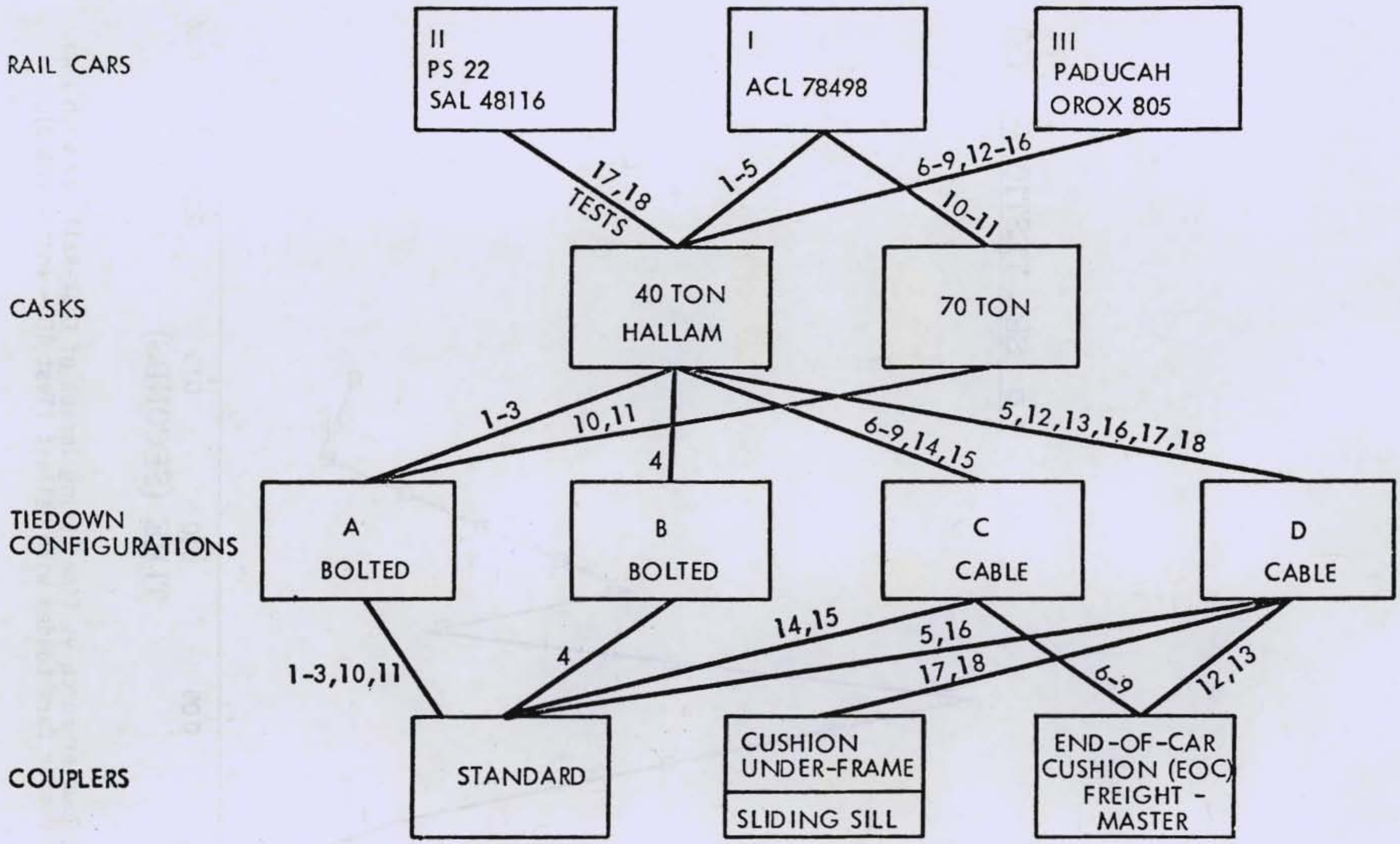

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FIGURE 2. Morphological Space Representation of Cask-Rail Car Coupling Tests.

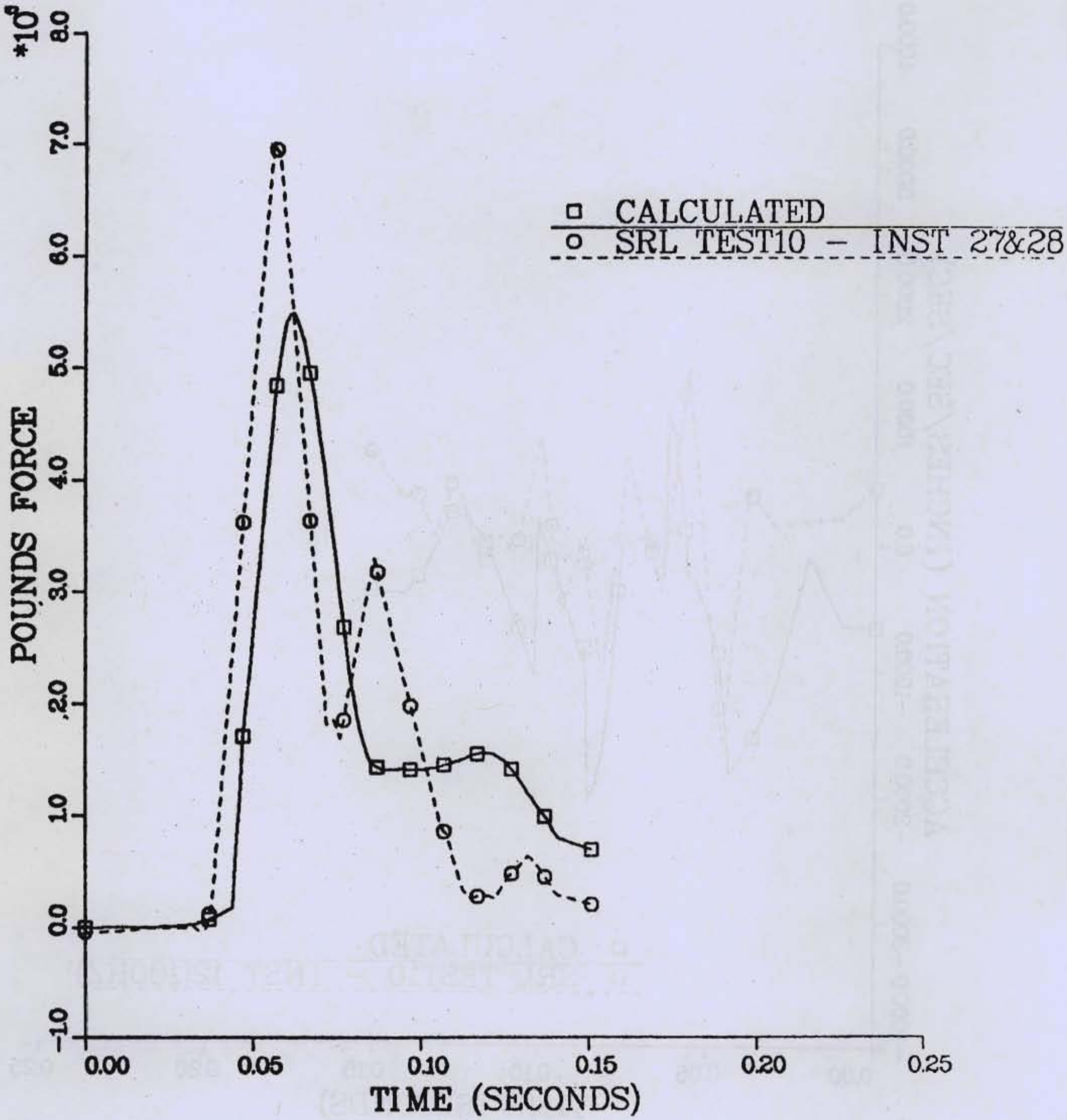

FIGURE 3. Horizontal Force of Interaction Between Cask and Rail Car vs Time During Impact with Four Hopper Cars Loaded with Ballast (Test 10 - Instruments 27 and 28).

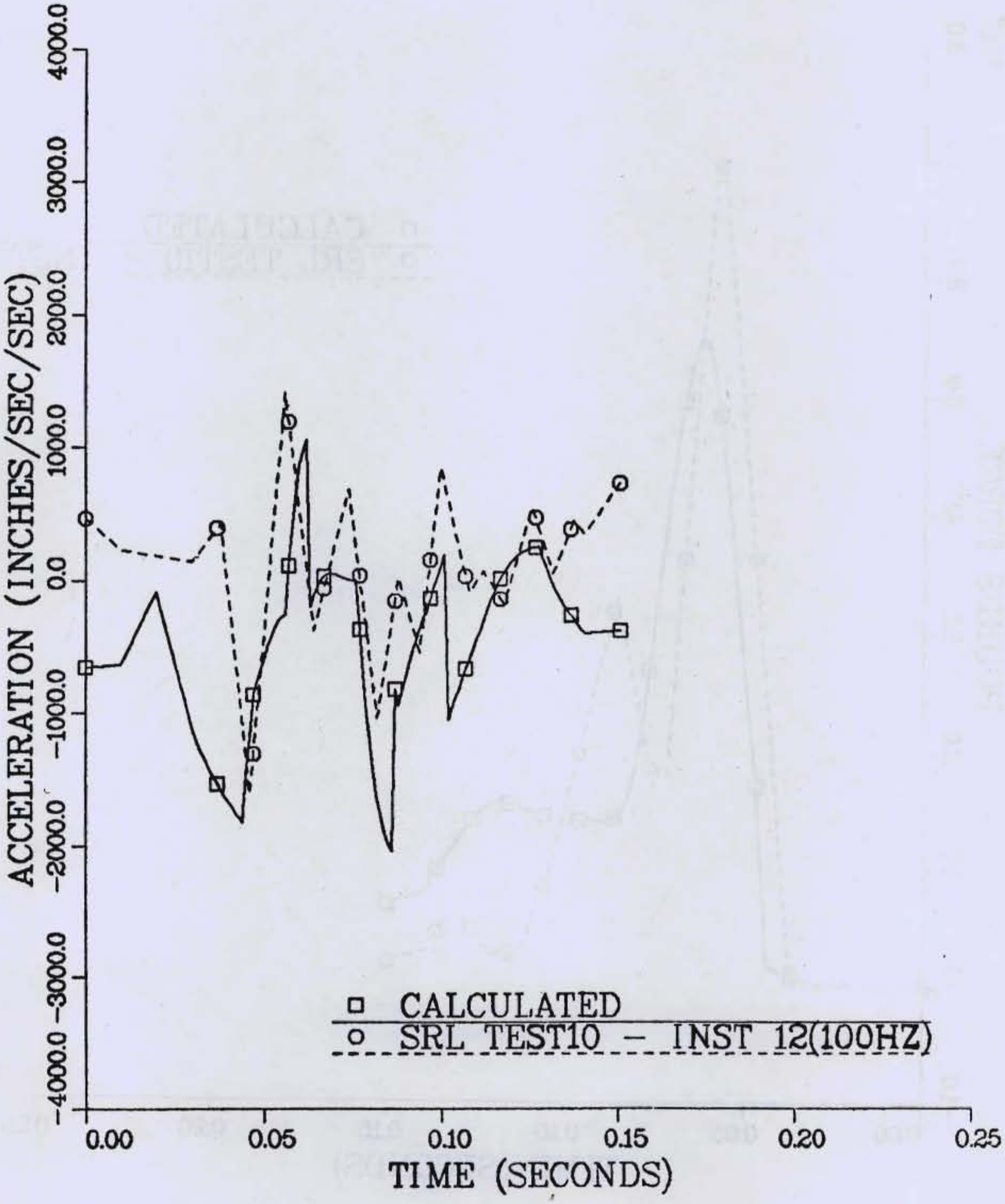

FIGURE 4. Horizontal Acceleration of the Cask-Rail Car During Impact with Four Hopper Cars Loaded with Ballast (Test 10 - Instrument 12: Filtered at 100 Hz).

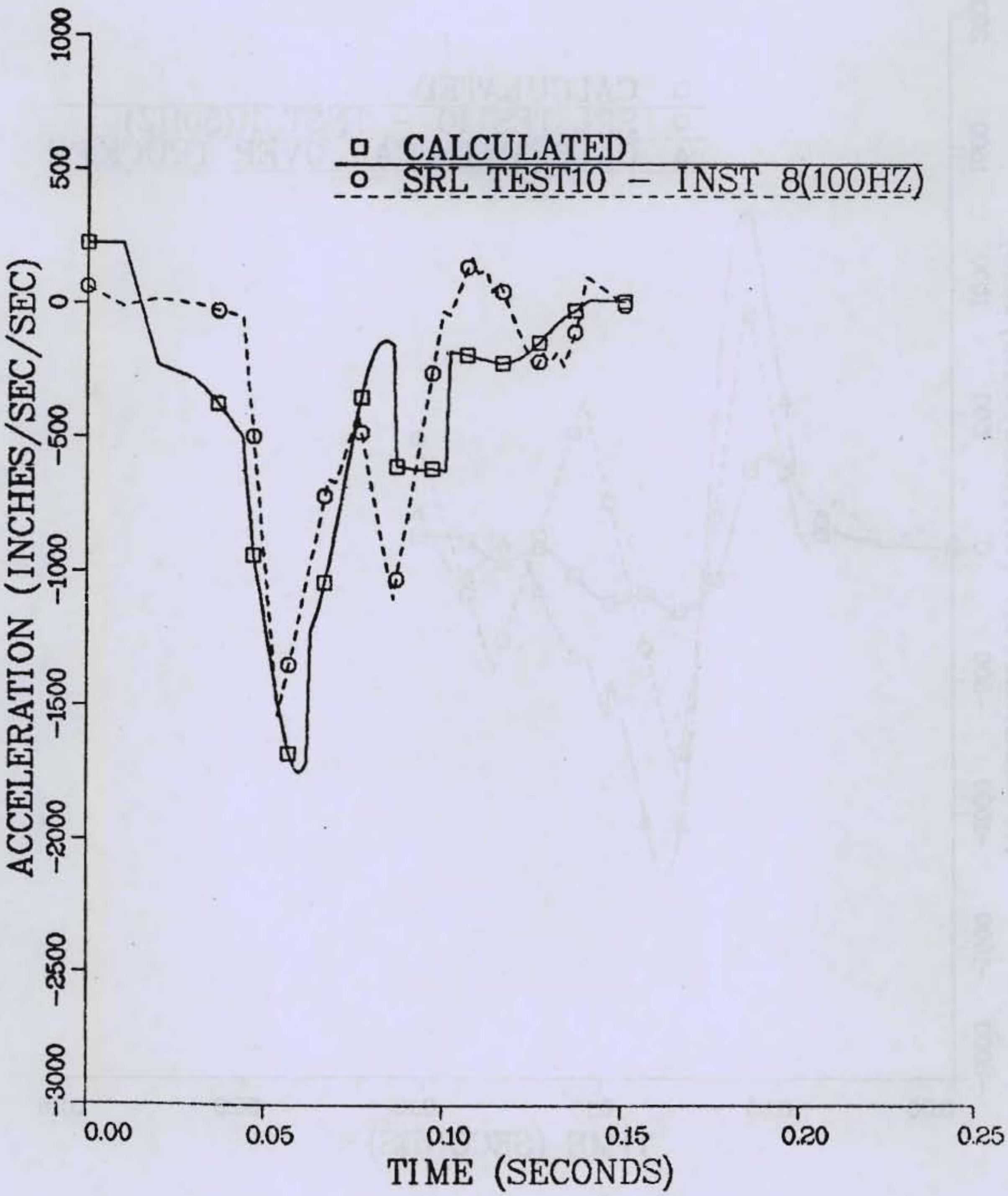

FIGURE 5. Horizontal Acceleration of the Cask During Impact with Four Hopper Cars Loaded with Ballast (Test 10 - Instrument 8: Filtered at 100 Hz).

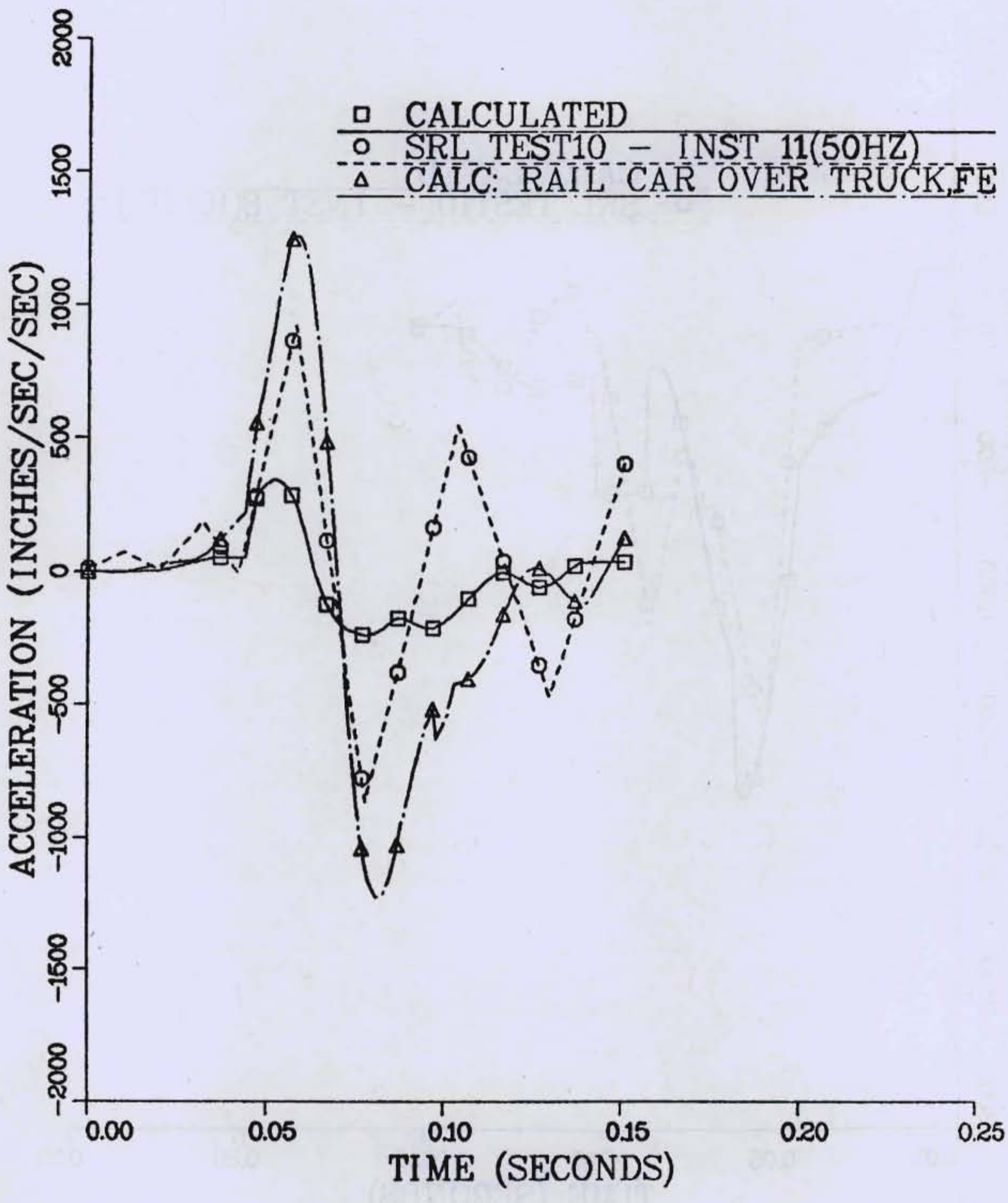

FIGURE 6. Vertical Acceleration of the Cask at the Far End During Impact with Four Hopper Cars Loaded with Ballast (Test 10 - Instrument 11: Filtered at 50 Hz).

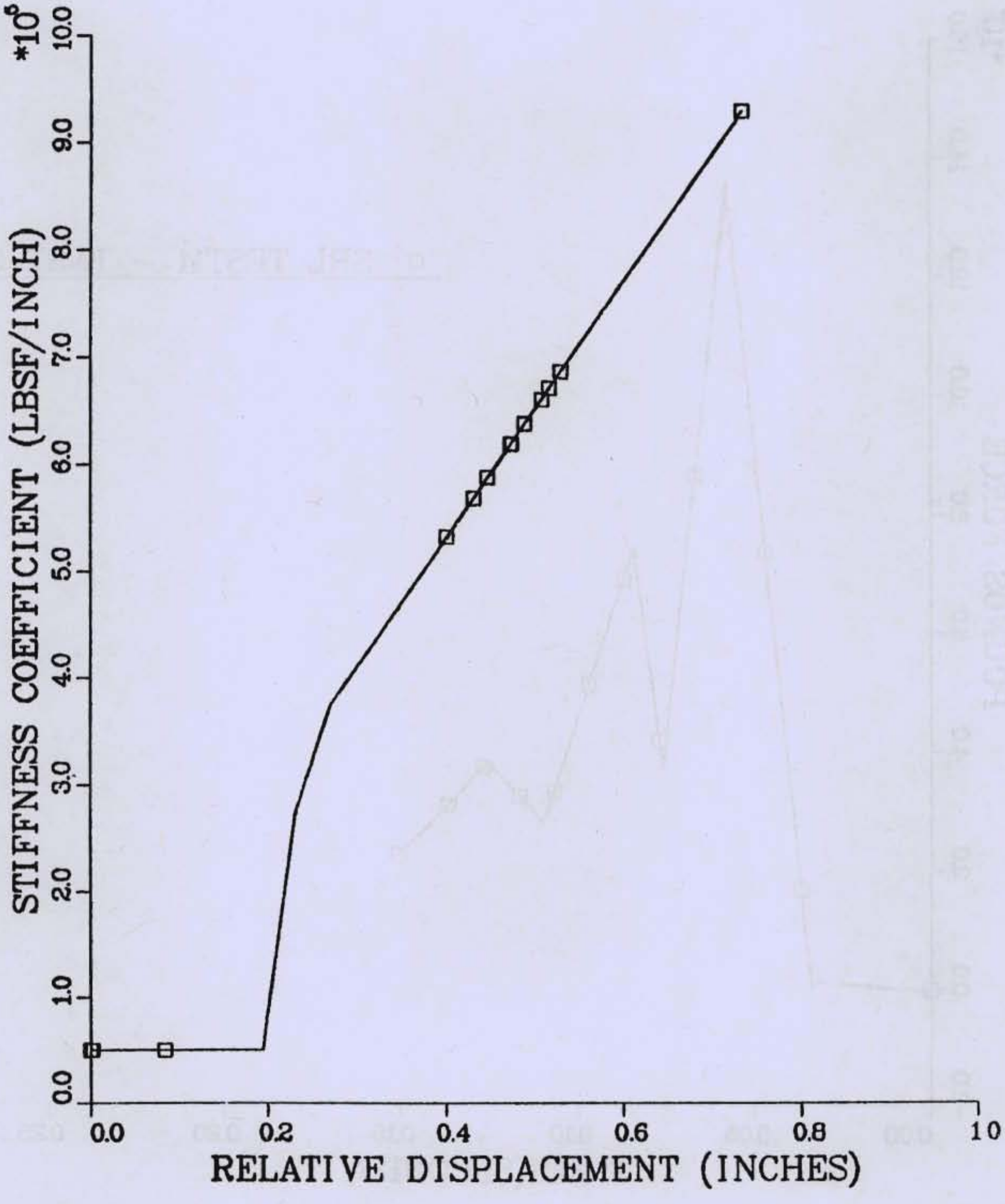

FIGURE 7. Stiffness Coefficient of Horizontal Component of Tiedowns vs Relative Displacement Between Cask and Rail Car (Tests 10 and 11).

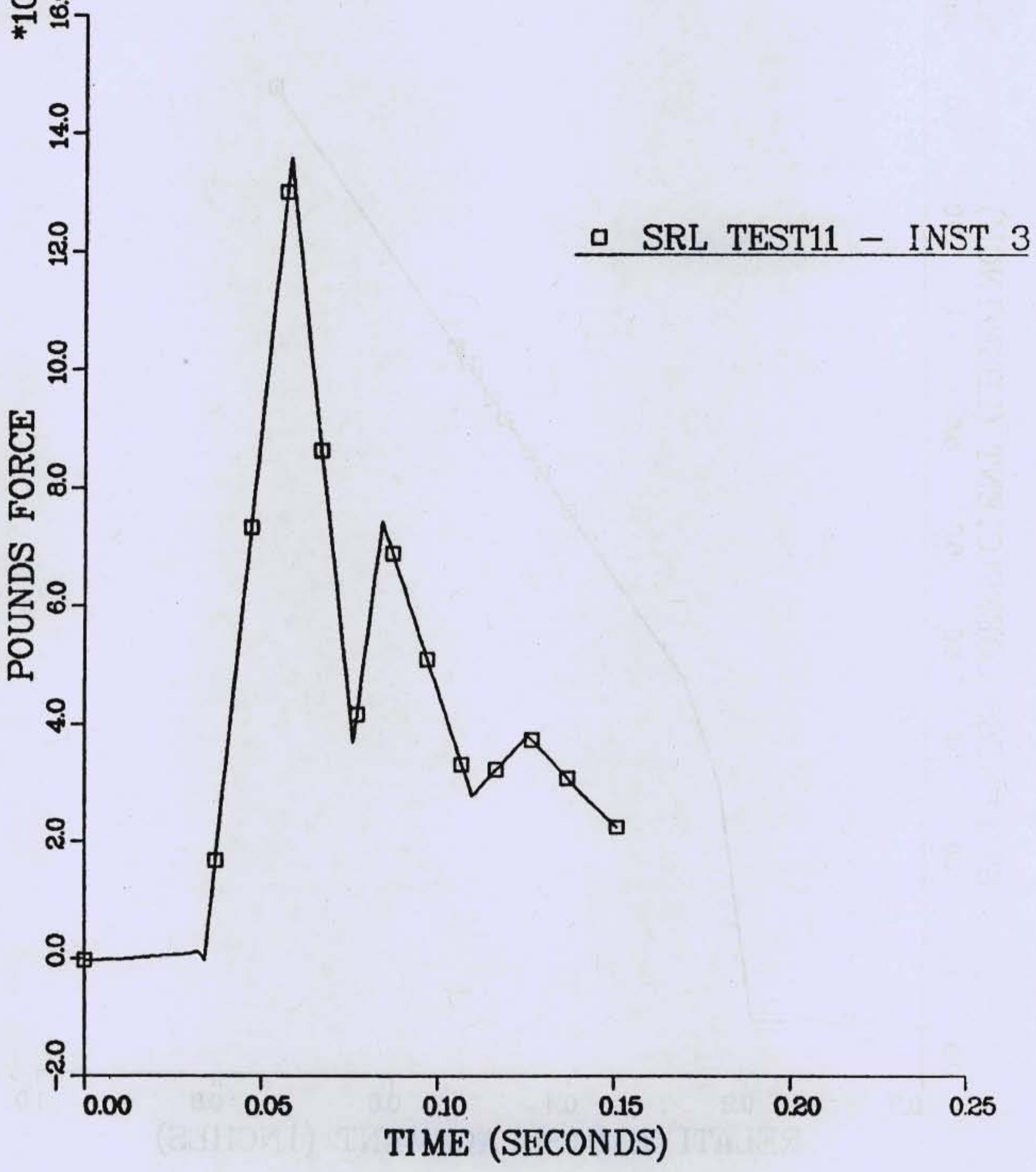

FIGURE 8. Coupler Force vs Time During Impact of Cask-Rail Car with Four Hopper Cars Loaded with Ballast (Test 11 - Instrument 3).

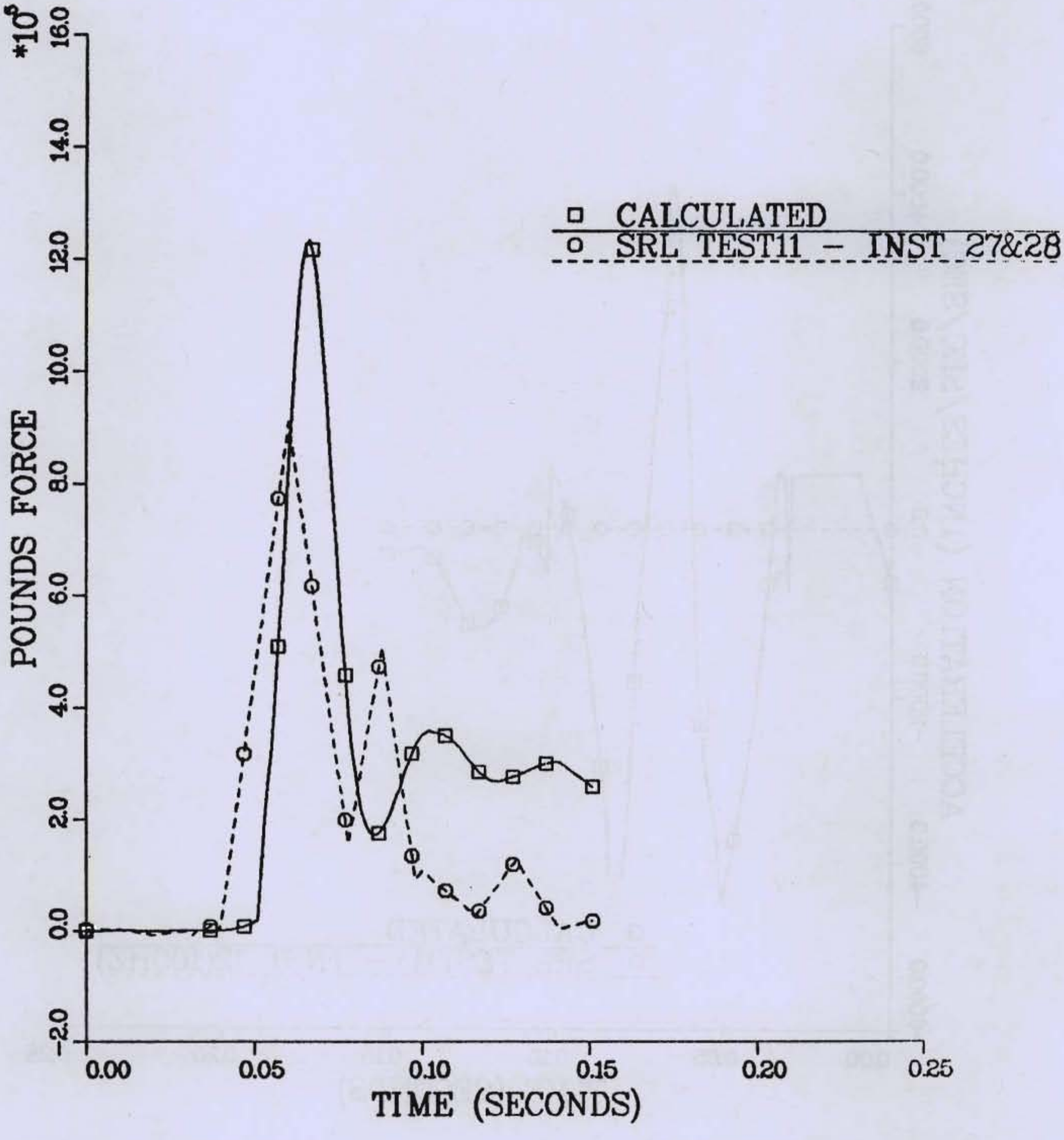

FIGURE 9. Horizontal Force of Interaction Between Cask and Rail Car vs Time During Impact with Four Hopper Cars Loaded with Ballast (Test 11 - Instruments 27 and 28).

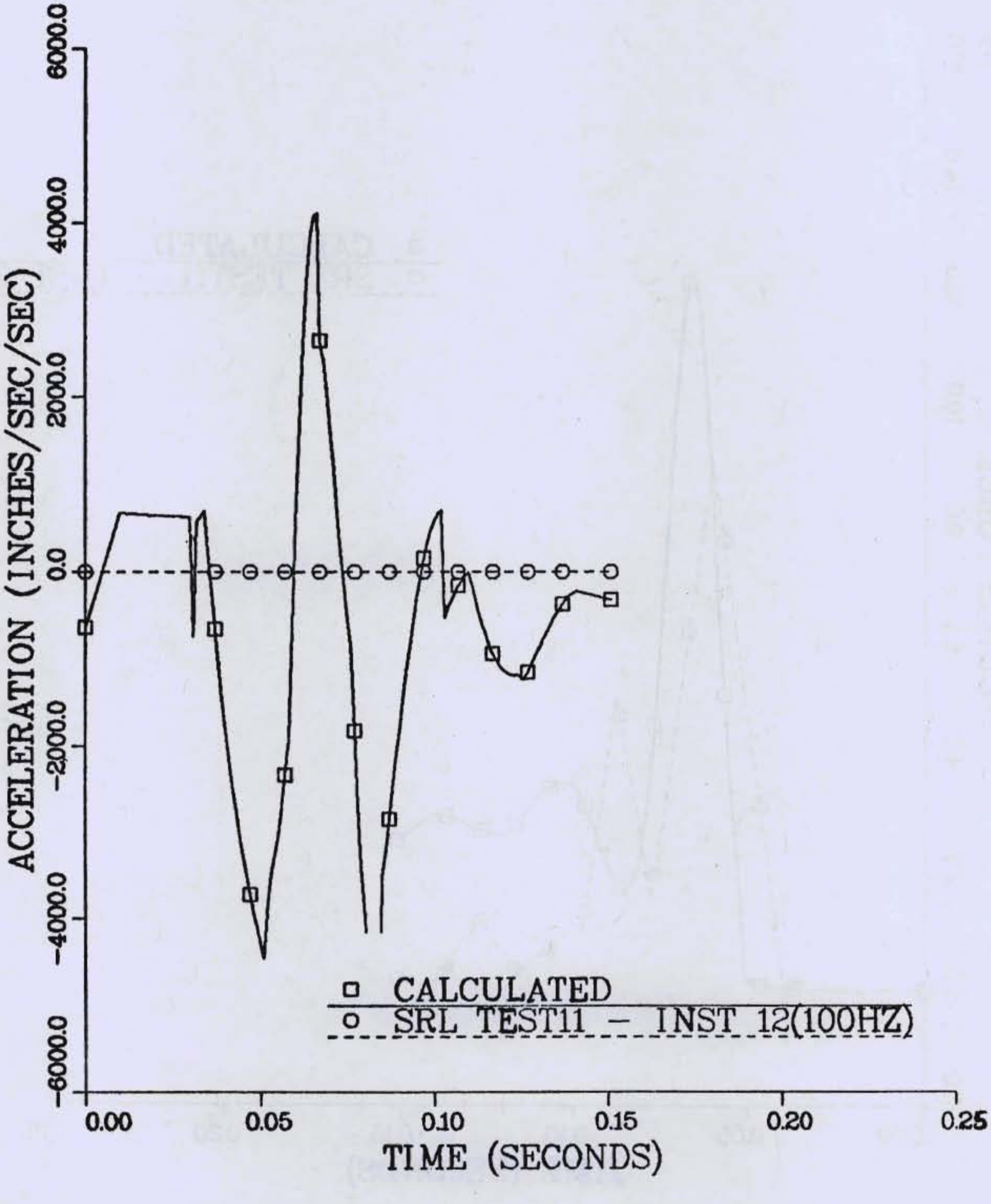

FIGURE 10. Horizontal Acceleration of the Cask-Rail Car During Impact with Four Hopper Cars Loaded with Ballast (Test 11 - Instrument 12: Filtered at 100 Hz).

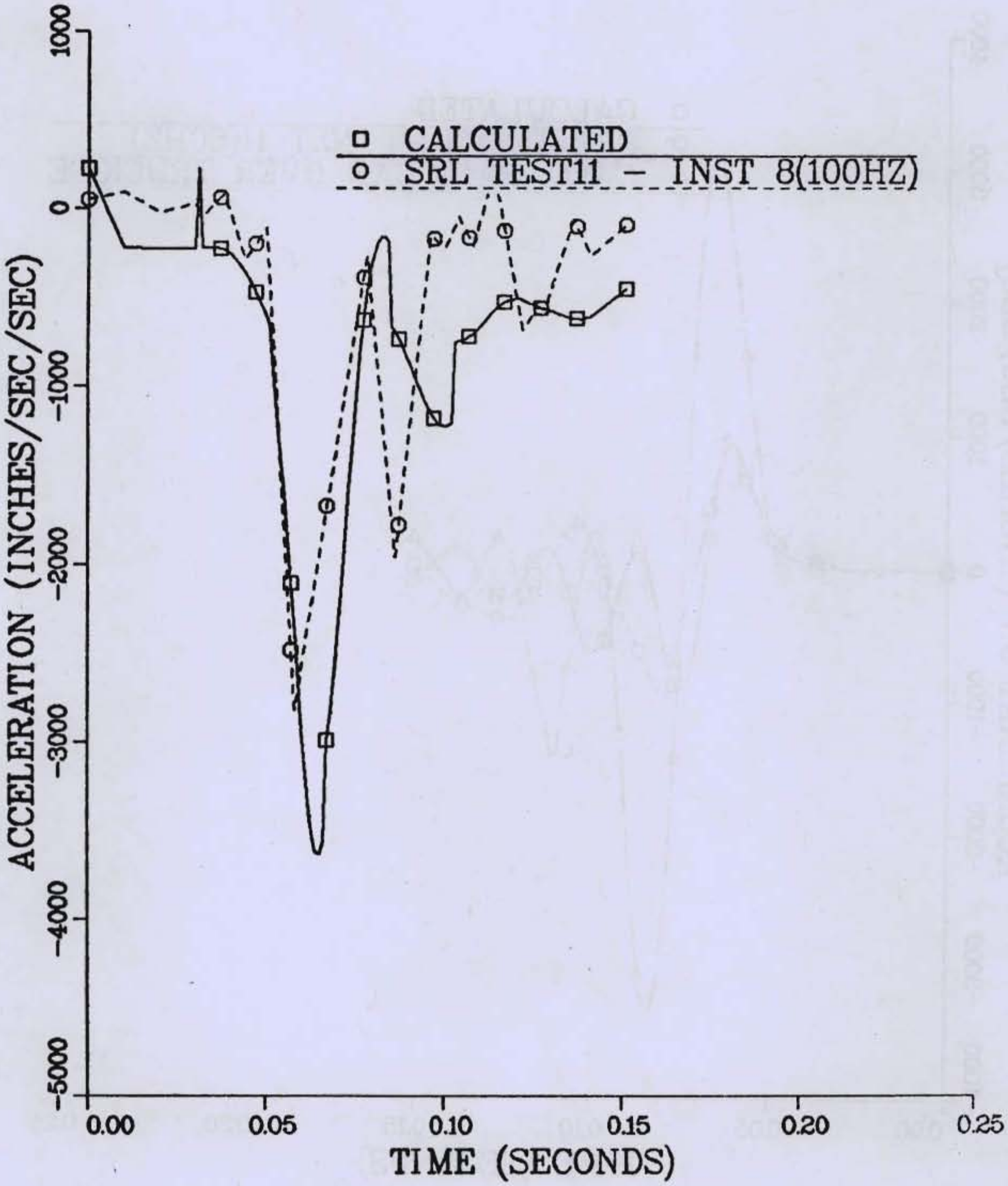

FIGURE 11. Horizontal Acceleration of the Cask During Impact with Four Hopper Cars Loaded with Ballast (Test 11 - Instrument 8: Filtered at 100 Hz).

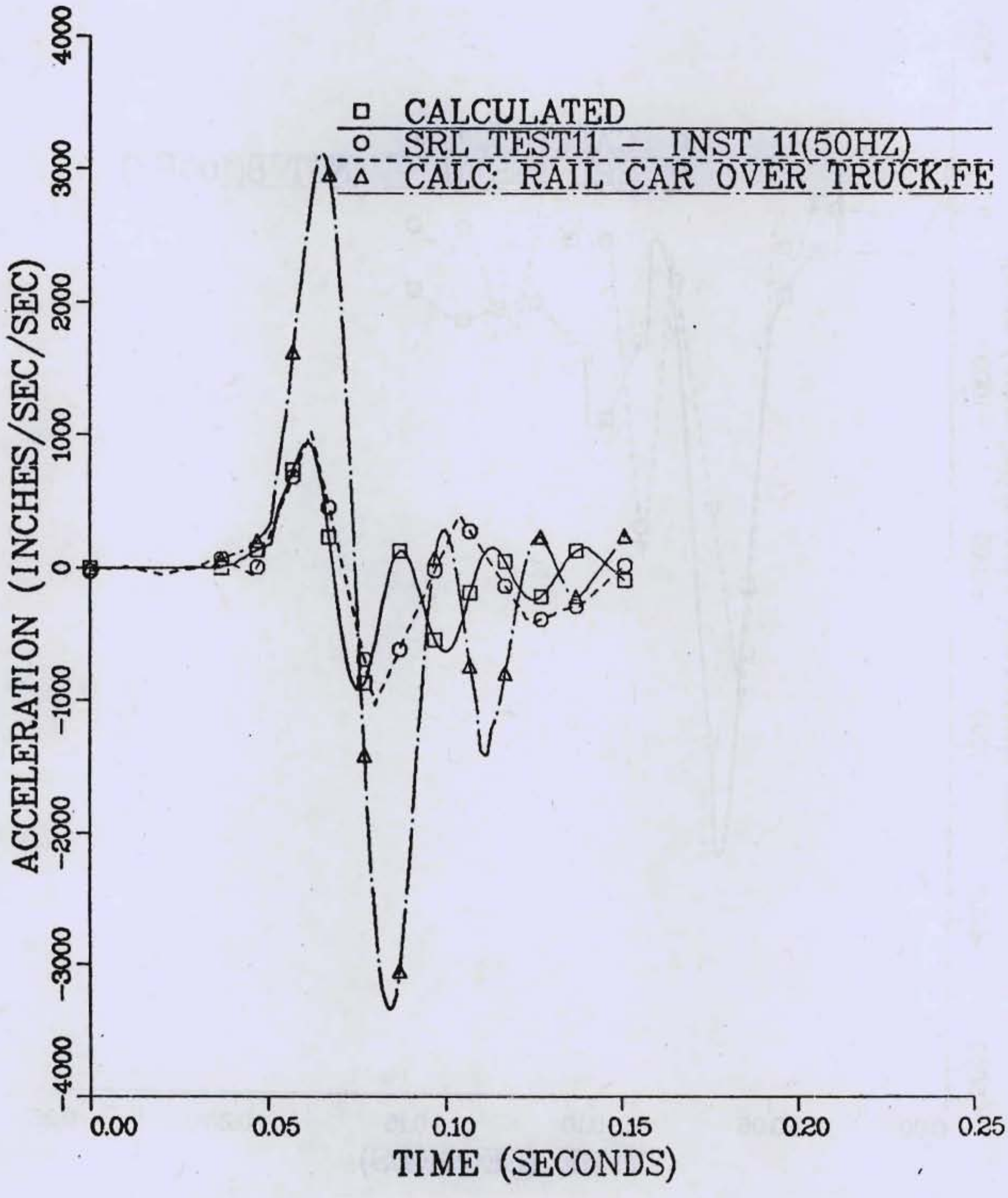

FIGURE 12. Vertical Acceleration of the Cask at the Far End During Impact with Four Hopper Cars Loaded with Ballast (Test 11 - Instrument 11: Filtered at 50 Hz).

APPENDIX B - TABLES

TABLE 1

SUMMARY OF CONFIGURATIONS AND CONDITIONS
OF COMPLETED CASK-RAIL CAR COUPLING TESTS

Test No.	Date	Rail Car	Coupler	Cask Wt. Tons	Impact Speed MPH	Stop Frequency f_n	Tiedown	Remarks
								Preliminary test no instrumentation
P1	6/8	III	Std	42.5	5.5	-	-	- Concrete simulation
P2	6/8	III	Std	42.5	7.6	-	-	- Welded Steel Stop
								- Cable Rigging to Restrain Weight
P3	6/8	.III	Std	42.5	11.8	-	-	- No structural damage
1	7/14	I	Std	40	8.3	Hi	A	Instrumented Coupler Faulty
2	7/18	I	Std	40	9.0	Hi	A*	Instrumented Coupler Faulty
3	7/19	I	Std	40	10.5	Hi	A	Instrumented Coupler Faulty
4	7/19	I	Std	40	10.7	Low	B	
5	7/20	I	Std	40	10.5	Hi	D	Cable Load Instruments Faulty
6	7/26	III	EOC	40	2.8	-	C	No Photography - No Data on Tape
7	7/26	III	EOC	40	5.6	-	C	No Photography - No Data on Tape
8	7/26	III	EOC	40	9.2	-	C	No Photography - No Data on Tape
9	7/26	III	EOC	40	9.2	-	C	No Photography - No Data on Tape
10	7/27	I	Std	70	8.0	-	A	One High Speed Camera Only
11	7/27	I	Std	70	11.2	-	A	One High Speed Camera Only
12	7/31	III	EOC	40	11.2	-	D	Data Questionable
13	8/1	III	EOC	40	11.2	-	D	Report of Test 13
14	8/1	III	Std	40	5.4	-	C	
15	8/1	III	Std	40	6.5	-	C	
16	8/2	III	Std	40	10.8	-	D	Some Cables Loose After Test
17	8/3	II	Cushion	40	5.9	-	D	
18	8/3	II	Cushion	40	10.7	-	D	

*Support Underbeam Reinforced (i.e., stiffened)

Key

Railcars:
- I 70 ton SCL - Std Couplers
- II 70 ton SCL - Cushion Underframe
- III 80 ton Union Carbide - Mixed Couplers

Tiedowns:
- A - 2 load cells between stop and cask bumper beams
  - 2 load bolts reproducibly snug
- B - Same as A, except f_n lowered with bumper beams
- C - Ten 1" cables at same angle - No stop
- D - Vertical Tiedown with six cables - two instrumented

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The CARDS (Cask Rail Car Dynamic Simulator) model was expanded to simulate the cask-rail car system used in Tests 10 and 11 of the series of rail car coupling tests conducted at the Savannah River Laboratories (SRL) in July and August of 1978. An assessment of how well CARDS simulates the behavior of this cask-rail car system was made by comparing calculated and experimental values of four response variables. The processing and interpretation of the data from Tests 10, 11, 13, 16, 17 and 18 of the SRL series been completed.

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